C1850-6
01/29/89 A

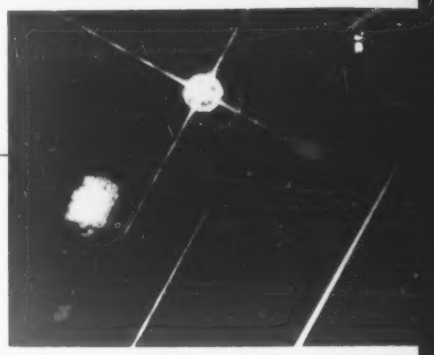
IR
Resea

Laser techniques unveil plasma secrets

Choose technology with staying power

R&D

CONTENTS



R&D BUSINESS

15 SUPERCOMPUTERS
Control Data bows out of market as Cray Research splits into two companies

16 FEDERAL BUDGETING
Science groups urge coordinated budgeting for Federal R&D dollars

NEWS

22 SPACE
Shuttle successes mask NASA's serious personnel problems; private space flight nets successful foaming experiment

24 SCIENCE POLICY
Bush names Bromley as science adviser; Bromley says U.S. faces challenges

26 ELECTRONICS
Project aims to improve GaAs capability

31 MATERIALS
Graphite yarns may change composite parts; PMR materials can take the heat

34 R&D FUNDING
British group calls for R&D tax program; 150% tax credit ups Australian research

39 NUCLEAR RESEARCH
EC continues R&D on old reactors

40 NONDESTRUCTIVE TESTING
Ultrasonic analysis improves sheet metal forming efficiency

40 COMMUNICATIONS
Beams of light flash under Atlantic

41 TECHNOLOGY TRANSFER
Venture capital fund will tap Federal R&D; AAAS hears Stanford president

SPECIAL REPORT

43 R&D 2000 COMMITTEE
Pro-technology group urges industry talks with Federal officials

FEATURES

COMPUTERS

54 **Can Your Computer Go the Distance?**

Hans T. Koppen and David S. Lindsey, Control Data Corp.
The authors' guidelines will help you choose a computer system that will remain competitive for years to come.

SPECTROSCOPY

62 **Aim a Laser at Your Plasma And Expose Its Secrets**

Mundiyath Venugopalan, Western Illinois Univ.
Individual plasma-analysis methods can be enhanced when used simultaneously or in combination.

LASERS

72 **Microlasers Offer New Reliability**

Philip E. Chumbley, Amoco Laser Co.
Efficient solid-state microlasers can attack problems in industry and R&D labs that other lasers can't.

MATERIALS

78 **As the Tubing Goes, So Goes the Pump**

James D. Pisula Jr., Norton Co., Performance Plastics Div.
New materials make it possible to select tubing that is almost ideal for a given peristaltic pump application.

VACUUM TECHNOLOGY

87 **Excited Dyes Improve Semiconductor Photosensitivity**

Prashant V. Kamat, Notre Dame Radiation Laboratory
Understanding how dye-coated semiconductors work helps to explain paint and solar cell mechanisms.

ABOUT THE COVER

***Fiber-optic cables benefit** from a new copolymer that combines the toughness of organic resins with the flexibility of inorganic silicones. The polymer, SILTEM, is a product of GE Silicones. Photo courtesy of the GE Research and Development Center.*

INTERNATIONAL JOURNAL OF RESEARCH, DEVELOPMENT, AND QUALITY ASSURANCE

DEPARTMENTS

3 R&D NEWS IN BRIEF

11 EDITORIAL

15 R&D BUSINESS

22 R&D NEWS OF SCIENCE AND TECHNOLOGY

43 SPECIAL REPORT

44 INDUSTRY EVENTS

51 LETTERS

87 VACUUM TECHNOLOGY

95 PEOPLE, ETC.

99 NEW PRODUCTS

103 READER SERVICE CARD

115 R&D PRODUCT CENTER

119 LITERATURE

129 SOFTWARE

132 ADVERTISERS INDEX

136 R&D TRENDLETTER

COLUMN

49 INNOVATIVE NOTEBOOK
Chemists are ecstatic about "fusion in a bottle," while physicists are skeptical and even hostile, says Fred Jueneman in "Cold fustian."

STAFF

Robert Cassidy
Editor-in-Chief

Gary L. Parr
Managing Editor

Charles S. Derra
Associate Editor, News

Timothy G. Studt
Associate Editor

Elizabeth Dougherty
Assistant Editor

Sandra Jean Brown
Editorial Production Manager

Joan Cacioppo
Editorial Assistant

Tina Lentz
R&D 100 Coordinator

Mary Hincker
Promotion Manager

Thomas Kane
Marketing Research

William J. Stanners
Comptroller

Frank Pruzina
Reprints

Timothy M. Kelly
Publisher and Vice President

Robert R. Jones
Executive Editor

Antonios Pronoitis
V.P. and Exec. Art Director

Judy Whitt
Director, Art Dept.

Donna Kurzydlo
Senior Art Director

Phillip Hanes
Associate Art Director

Patricia Miller
Business Manager

Marylyn Dorsett
Advertising Sales Assistant

Laura Smith
Advertising Production

Linda Saiz
Advertising Contracts

Ruben Natal
Circulation Manager

Editorial, Executive, and Sales Offices
Box 5080, Des Plaines, IL 60017-5080, USA. Telephone 312/635-8800

EDITORIAL BOARD

C.J. Mosbacher, former Editor *R/D* and Executive Editor *R&D*, Chairman
Anna D. Barker, Senior Vice President, Battelle Technology International
H. Kent Bowen, Ford Professor of Engineering, Massachusetts Inst. of Technology
R.F. Bunshah, Professor of Engineering, Univ. of California–Los Angeles
E. Richard Cohen, Distinguished Fellow, Rockwell International Science Center
Raymond R. Fessler, Director, Basic Industry Research Lab, Northwestern Univ.
Paul Kucera, Analytical Development, Lederle Laboratories
Milos V. Novotny, Department of Chemistry, Indiana Univ.
Alan Schriesheim, Director, Argonne National Laboratory
Dan W. Urry, Molecular Biophysics, Univ. of Alabama at Birmingham

Laboratory of the Year Program Adviser
Fred L. Bernheim, FARA, Bernheim & Kahn Ltd., Architects

Microlasers Offer New Reliability for R&D

Efficient solid-state microlasers in industry and R&D labs can attack problems other lasers can't address.

By Philip E. Chumbley, Amoco Laser Co.

R&D

THE AUTHOR

Philip E. Chumbley is product manager at Amoco Laser Co., Naperville, IL. Previously he was manager of production and manufacturing and did research with the integrated materials group. Chumbley received a BS in engineering physics at Univ. of Illinois, Champaign-Urbana, and a PhD in physics from Univ. of Missouri, Columbia.

FIRST, THROW the laser against the wall. Next, kick it across the floor. Now stomp on it a few times. Then pick it up; slip it into a laser mount; plug it in; turn it on; and use it to make sensitive measurements that require excellent beam profile, high stability, and low noise. . . .

Are we dreaming? No. Not if the laser is a microlaser.

Microlasers represent a new class of miniaturized, all-solid-state laser devices based on the emerging technology of diode-laser pumping of a solid-state crystal. The advantages of these new products range from improved performance that has been unattainable with many earlier lasers to greater ease of manufacturing the products.

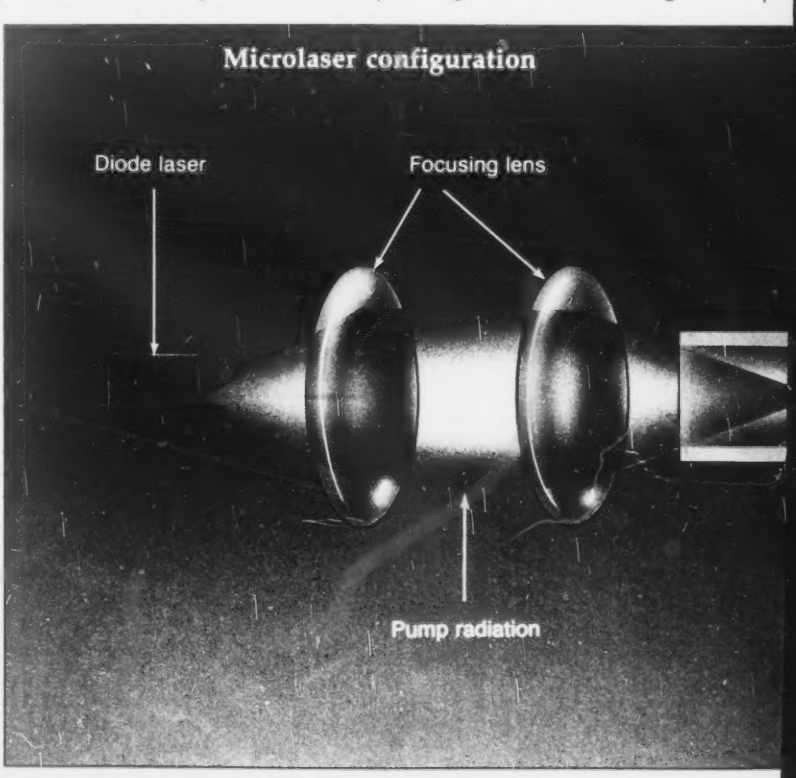
Compared to gas-discharge lasers, microlasers offer greatly improved efficiency, reliability, and compactness. These advantages permit microlasers to address research and industrial problems that cannot be served by conventional laser technology.

Examination of the projected 1989 laser market showed that diode lasers make up the largest single category (1). Nevertheless, total laser sales include large numbers of systems based on gas-discharge technology.

Examples are helium-neon (HeNe) lasers, which employ a gas-filled tube for the laser cavity. Also included are the flashlamp-pumped solid-state lasers such as yttrium-aluminum-garnet (YAG). Other examples are helium-cadmium, carbon dioxide, and argon-ion lasers.

In fact, until the advent of the diode laser, virtually every laser sold was based on gas-discharge technology. Sales of these gas-discharge lasers amounted to more than $400 million in 1988 (2).

Still, gas-discharge technology suffers from several built-in problems. One of these is the reliance on a gas-filled glass tube that is fragile—the



manufacture of which is labor intensive. Lifetimes of these glass tubes typically are a few thousand hours or less.

It is difficult to fabricate small glass tubes that can meet pressure and durability requirements. Therefore, most of the tubes have bulky shapes and must be carefully packaged to avoid breakage.

Even in solid-state lasers, which use durable solid-state crystals for the gain medium, the durability is compromised when glass-tube flashlamps are included as pump sources.

To implement gas-discharge technology, it also is necessary to generate high voltages (usually >1,000 V) to cause an electrical discharge in the gas.

To make matters worse, electrical-to-optical efficiencies range from 0.02% for a HeNe laser to 0.002% for an argon-ion laser—and even lower for HeCd lasers and others. Even solid-state lasers, such as YAGs, have efficiencies of only 0.1% when they are flashlamp-pumped.

Microlasers, on the other hand, offer all-solid-state construction. In a typical microlaser configuration, the pump source is a semiconductor diode laser that is focused into a solid-state crystal such as YAG or yttrium lithium fluoride.

Unlike flashlamps, which emit across a broad spectrum, the narrow output of the diode laser can be temperature-tuned to match the absorption bands of the lasing crystal. This technique yields electrical-to-optical efficiencies approaching 10%.

In addition, lifetimes for the pump diode lasers vary from 20,000 to 40,000 hr, compared to about 7,000 hr for a HeNe tube (3).

The absence of a glass tube makes the microlaser rugged and compact. The diode-laser pump source can withstand severe mechanical shock and is much smaller than a flashlamp.

In turn, the high absorption of pump radiation achieved by tuning the pump output to match the absorption bands in the gain medium allows the use of a smaller solid-state crystal than otherwise would be needed. This, of course, permits an additional decrease in size. Hence, the term *microlaser*.

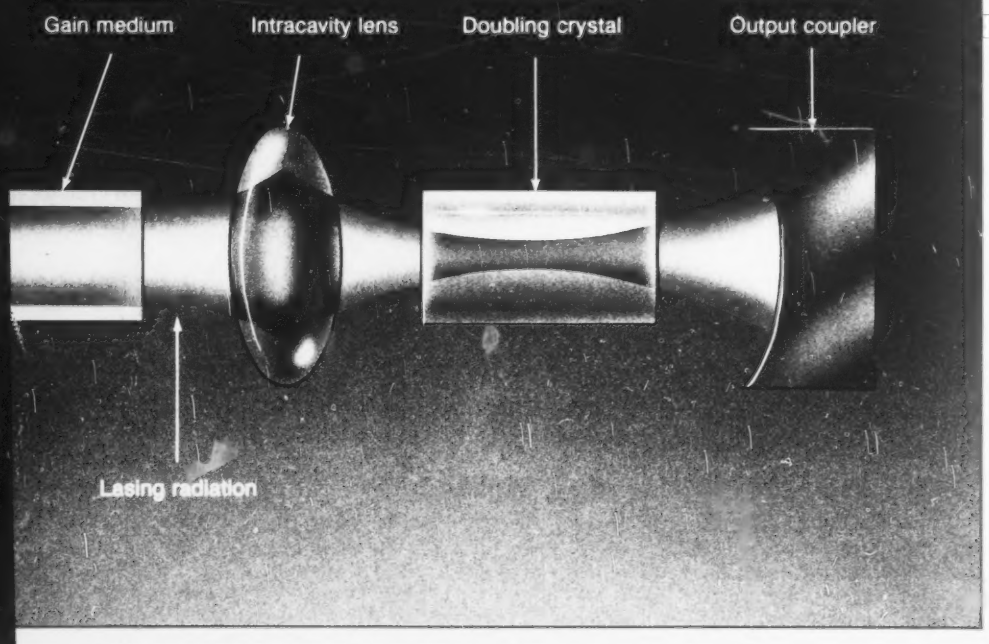
The reduction in package size results in additional advantages. A shorter laser cavity has faster rise times and will support fewer longitudinal modes than will a conventional laser.

Furthermore, mirror-alignment tolerances are not as critical as they would be in a longer cavity. Thus, manufacturing of the microlasers is easier, and the new devices are less sensitive to mechanical shock than are conventional lasers.

Frequency doubling

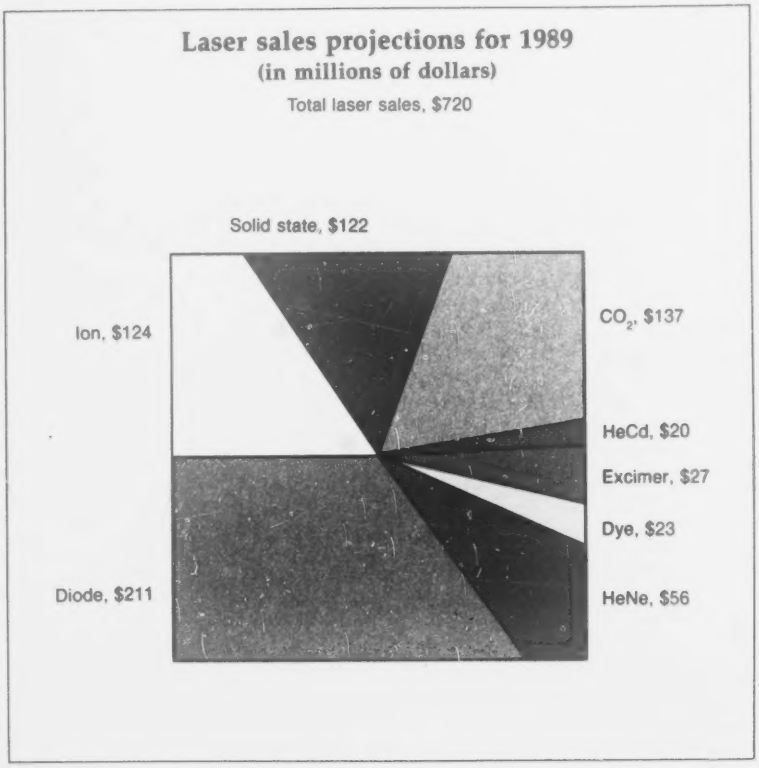
The introduction of an intracavity frequency-doubling crystal permits a microlaser that ordinarily emits radiation in the infrared region to produce visible light. By using different laser host materials coupled with various solid-state doubling crystals, the experimenter can obtain laser outputs that span the entire visible spectrum.

For example, intracavity doubling of a YAG microlaser that operates at 1,064 nm produces green light at 532



In a microlaser, the narrow output of the diode pumping laser can be temperature-tuned to provide efficiencies approaching 10% vs 1% for gas-discharge lasers.

Frequency doubling of lasing wavelengths can produce new, shorter wavelengths.



The laser market for 1989 is dominated by diode lasers as the single largest category, but total laser sales still depend heavily on gas-discharge technology.

nm. A different YAG laser that operates at 1,320 nm can be frequency doubled to give red light at a frequency of 660 nm.

In these two examples, the solid-state materials are the same; the only differences are the mirror coatings and the crystal orientation of the doubling crystal. That is, chemically identical materials have produced lasers with two totally different wavelengths, red and green.

Intracavity doubling allows multiple passes of the fundamental-frequency photons through the crystal. This capability results in a higher conversion efficiency than would be possible if the doubling crystal were placed outside the cavity.

In a similar manner Brewster plates can be added inside the cavity to provide polarized output with minimal loss of intensity, compared to a 50% intensity loss when unpolarized light is passed through an external polarizer.

Since microlasers are pumped by diode lasers, relatively high-powered microlasers can be obtained simply by inserting a high-powered diode laser. At the present time, diode lasers with output power greater than 1 W are available, and powers greater than 10 W will be attainable in the near future. In addition, it is possible to directly modulate diode lasers—something that cannot be done easily with gas-discharge tubes.

Often, laser users will ask: Why should we pump a solid-state crystal with a diode laser? Why not simply use the diode laser itself? The answer lies in the beam quality and in the ability of the laser to reach different wavelengths.

Microlasers produce Gaussian beams (*i.e.*, the beam intensity observed across the beam follows a standard distribution curve), while the intensity observed across a diode-laser beam shows alternate high-intensity and low-intensity zones. This Gaussian (TEM_{00}) diffraction-limited beam readily accepts frequency doubling, or summing, through the crystal.

Since different fundamental wavelengths are available through the use of various host crystals, frequency doubling of the lasing wavelengths can produce new, shorter wavelengths than have been available with other systems.

Manufacturing microlasers

One of the major advantages of microlasers is the fact that these devices can be readily made by high-volume manufacturing techniques.

Historically, the laser marketplace has been divided into a large number of segments, with a correspondingly large number of laser products designed to address these segments. This segmentation of laser products, each of which occupies its own small niche in the industry, has discouraged the development of high-volume, low-cost manufacturing techniques such as those found, for example, in the electronics industry.

In the manufacture of microlasers, however, the solid-state crystals and the optics are physically identical, except for the optical coatings. Thus, these components can be interchanged to produce microlasers that emit radiation at different wavelengths.

In the green and red frequency-doubled examples described earlier, the two microlasers look identical. Therefore, manufacturers can use the same techniques to produce totally different products. This continuity of manufacturing for a wide variety of products results in high-volume production at reduced cost.

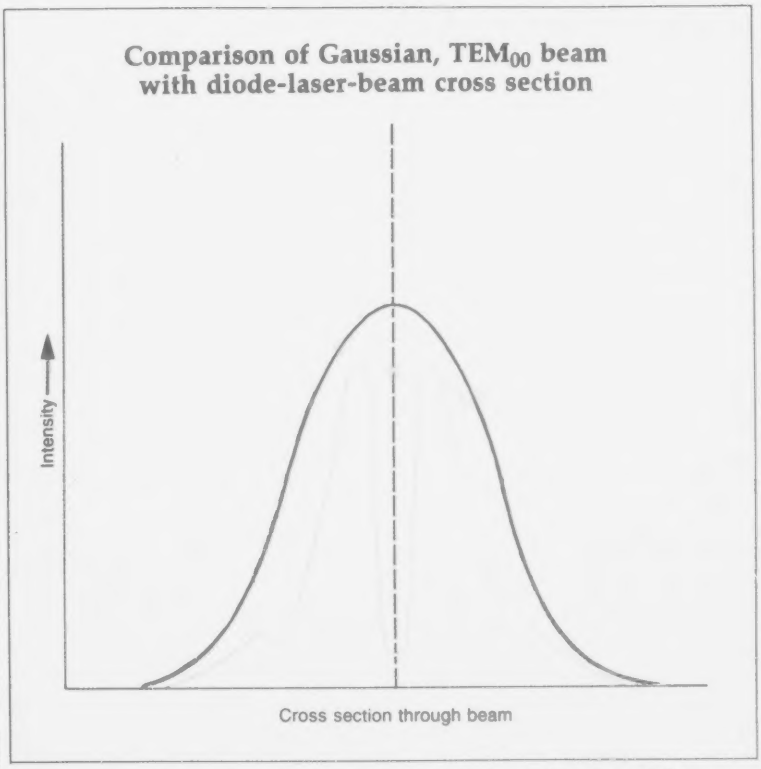
Microlaser applications

Listing applications for microlasers is like trying to list applications for the transistor when it first was introduced into the electronics industry. The obvious application is as a replacement technology, *i.e.*, microlasers for gas-discharge lasers, just as transistors replaced vacuum tubes.

Yet the real promise lies in applications that do not exist today but will be made possible by microlaser technology. Small size, high efficiency, and ruggedness will allow microlasers to address applications that previously were denied to the laser industry.

Meanwhile, here are a few of the

Microlaser applications include microsurgery, telecommunications, and optical alignment.



***Microlasers produce a Gaussian beam** that is conducive to frequency doubling through the crystal, allowing the solid-state lasers to offer new, short wavelengths.*

present-day applications open to penetration by microlasers:

• Testing and inspection. Compact, highly reliable microlasers can be used in harsh manufacturing environments for testing and inspection of optical components, thin films and coatings, optical fibers, and semiconductor devices.

• Optical alignment. Small, efficient microlasers can be used to align large, complex, high-powered laser systems of the same wavelengths that are used in medical, military, industrial, and R&D applications.

• Materials characterization. The high stability, low noise, and high beam quality of microlasers allows rapid, reliable characterization of solid-state crystals, semiconductor materials, and gases.

• Micromachining and microsurgery. The diffraction-limited output of microlasers allows them to be focused to beam diameters less than 5 μm. The resulting power density in the focused spot can exceed 10^6 W/cm^2. This is sufficient to melt or vaporize many materials.

• Telecommunications. The small size, reliability, and available wavelengths of microlasers, together with their ultralow noise, make these devices useful for data transmission, especially in fiber-based systems. While the modulation rate of YAG laser systems is limited to about 100 MHz, the frequency-summing techniques available in microlasers extend the modulation rate into the GHz range (4).

• Research and development. Flashlamp-pumped YAG lasers are basic tools in university, industry, and government R&D labs throughout the world. In these labs, compact, efficient, inexpensive microlasers can address many of the applications now being served by large, bulky gas-discharge lasers. In addition, improved stability and low noise make microlasers attractive in these areas.

• Optical storage. Short wavelengths with a diffraction-limited beam, plus low noise, make microlasers ideal for laser writing and reading of information on an optical disk (5).

• Military applications. The compact size, reliability, and ruggedness of microlasers allow their use as range finders, target designators, and instrument alignment devices.

• Entertainment. The small size, reliability, and excellent beam quality of visible-light microlasers will be important in projection television, film writing, and laser-signal transmission.

Where do we go from here?

The future of microlasers lies in developing new wavelengths and higher powers. In our lab, we have identified at least 20 different wavelengths suitable for microlaser construction. Continued research on new materials promises to identify even more wavelengths. For example, green, red, and blue microlasers already have been developed—as have polarized, Q-switched, and single-mode models.

In addition, high-power diode lasers, now being developed in several laboratories around the world, will allow increased output powers. With increases in power and range, microlasers can replace even more of the gas-discharge types in use at present, and they will create new applications that are limited only by the imaginations of the people who introduce microlaser technology to new fields. **R&D**

References

1. Kales, David, "1989 Laser Economic Review and Outlook, *Laser Focus World*, January 1989, p 102.
2. *Ibid.*, p 106.
3. Harnagel, G.L., *et al.*, "Accelerated Aging of 100-mW CW Multiple-Stripe GaAs Lasers Grown by MOCVD," *Appl. Phys. Lett.*, 46, No. 2 (1985), p 118.
4. Anthon, D.W., *et al.*, "Nd:YAG-Diode Laser Summation in KTP for a High Modulation Rate Blue Laser," presented at OE-Lase, SPIE conference, Los Angeles, CA, January 1988.
5. "Blue Microlaser," *Photonics Spectra*, December 1987, p 34.

READER RESPONSE PANEL

Please help *Research & Development*'s editors serve you better. Rate your interest in this article by circling the appropriate number on the Reader Service Card.

High **383** Medium **385** Low **387**

PRODUCT UPDATE—NICOLET'S SYSTEM 500

New Power in Waveform Acquisition and Analysis

Unique software helps make the System 500 "turn-key" ready

At first glance, Nicolet Instrument's unveiling of its new System 500 seems newsworthy because of the 500's industry-leading hardware. Indeed, in the world of waveform aquisition and analysis, where more is better, the System 500 is in a class by itself. The 500 has more channels, more memory, more speed and more resolution.

Each digitizer board, with its own independent trigger circuitry, time base and up to 1 megasample record length, is worthy of a full review. This multi-channel system can be configured to have as many inputs you need — up to several hundred. The digitizer boards are designed to be the equivalent of having a 12 bit digital scope on a card.

Turn-key system

But after you get your hands on the System 500, the the most important news becomes apparent. Someone has finally developed a very powerful, competitively priced system for waveform aquisition and analysis that truly is a "turn-key" system.

You literally can take this system out of the box, plug in the power cord, connect the GPIB cable between the aquisition unit and the controller, and turn it on. The System 500 is now ready to take data. This turn-key readiness promises to save time by considerably reducing the learning curve needed to perform complex waveform aquisition and analysis.

Intuitive windows software

The primary reason for System 500's easy operation is Nicolet's unique software which operates under Microsoft Windows/386™. The powerful Nicolet software can easily be controlled through pulldown menus that can be accessed by mouse or keyboard.

Measuring waveforms becomes as simple as pointing to the data point of interest on a waveform and clicking the mouse — the voltage and time values for the selected point is immediately displayed on the screen. By using the Delta Numerics function relative measurements like peak to peak or rise time can easily be made.

Also, Nicolet's unique software, combined with the System 500's built–in processor and co-processor, make incredibly fast waveform processing and analysis possible.

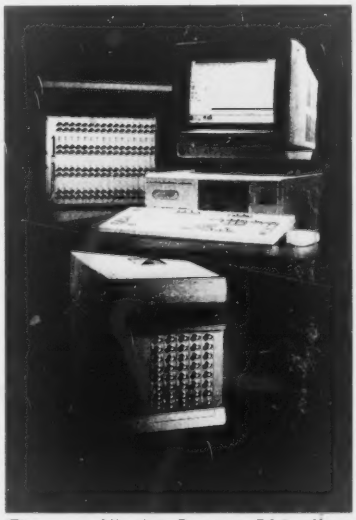
Local processing

While other data aquisition systems need to transfer data to another computer for analysis, Nicolet has built calculation capabilities into the new System 500. Complex calculations can be performed on acquired data as it resides in the digitizer's memory.

There is no need to transfer data to a computer for analysis, no need for complex programming to handle normalizing sets and long record lengths. Functions are performed on the powerful 32 bit processors with a few clicks of the mouse. This local processing of data greatly decreases the time it takes to generate answers.

The bottom line is that the System 500 is a unique turn-key waveform acquisition system. For full details you'll need to read the product brochure.

Call Nicolet Test Instruments (800) 356-3090



The new Nicolet System 500 offers multi-channel flexibility with up to 10 MegaSamples/Second digitizing rates.

Advertisement
For information circle **204**

R&D

Research & Development (ISSN 0746-9179) is published monthly except semimonthly in February and March by The Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington St., Newton, MA 02158-1630. Terrence M. McDermott, President; Charles E. Moodhe, Senior Vice President/General Manager, Chicago Division; Jerry D. Neth, Vice President/Publishing Operations; J.J. Walsh, Financial Vice President/Magazine Division; Thomas J. Dellamaria, Vice President/Production and Manufacturing; Timothy M. Kelly, Vice President and Publisher; Neil P. Ruzic, founder of *Industrial Research*.

Circulation records are maintained at Cahners Publishing Company, 44 Cook St., Denver, CO 80206-5800 (phone: 303/388-4511). **Circulation:** More than 120,000 copies distributed. Second-class postage paid at Denver, CO 80206-5800, and at additional mailing offices. **Postmaster:** Send address corrections to *Research & Development* at our Denver address.

Subscription rates for nonqualified people: USA, 1 yr $45, 2 yr $85; Canada and Mexico, 1 yr $55, 2 yr $100; all other countries, 1 yr $80, 2 yr $150; air mail surcharge, 1 yr $45, 2 yr $90. Except for special issues where price changes are indicated, single copies of regular issues are available for $10. Address all subscription mail to *Research & Development*, 44 Cook St., Denver, CO 80206-5800. Include zip code and, for change of address, copy of old label.

Research & Development copyright 1989 by Reed Publishing USA; Ronald G. Segel, Chairman and Chief Executive Officer; Robert L. Krakoff, President and Chief Operating Officer; William M. Platt, Senior Vice President.

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means electronic or mechanical, including photocopying, recording, or by any information storage retrieval system, without written permission of the copyright owner. Prices for bulk reprints of articles available on request. Copies of back issues are available from University Microfilm, 300 N. Zeeb Rd., Ann Arbor, MI 48106, and on microfiche from Micro-Photo Div., Bell & Howell, Old Mansfield Rd., Wooster, OH 44691. *Research & Development* articles are indexed in Engineering Index, Current Contents, and New York Times Information Bank.

Cahners Publishing Company, A Division of Reed Publishing USA □ Specialized Business Magazines for Building & Construction □ Manufacturing □ Foodservice & Lodging □ Electronics & Computers □ Interior Design □ Printing □ Publishing □ Industrial Research & Technology □ Health Care □ Entertainment □ Specialized Consumer Magazines: American Baby □ Modern Bride.

ABP BPA ABC